

Uses and mechanism of action of main ingredients in sunscreen products

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Article Received: 16 March 2024

Article Accepted: 22 May 2024

Article Published: 27 May 2024

ABSTRACT

Today, with the strong development of industrialization and modernization, countries around the world are suffering the severe consequences of climate change, global warming, etc. Our atmosphere are strongly impacted, causing thinning, tearing, and puncture of the ozone layer, causing ultraviolet rays to directly impact human skin. In the modern age, the importance of protecting the skin from the effects of UV rays from the sun has become more important than ever. Increased exposure to sunlight, along with depletion of the ozone layer, has increased the risk of skin-related problems, including skin cancer and premature aging. Sunscreen is not only an important tool to protect the skin from the harmful effects of UV rays, but also helps the skin become smoother and healthier. However, the sunscreen market is increasingly diverse with a variety of products and formulations, and choosing a suitable product is not always easy. Understanding the role and importance of sunscreen to human skin and health, this article presents the uses and mechanisms of action of the ingredients in sunscreen.

Keywords: Sunscreen; UV rays; UVB rays; UVC rays; SPF index; PA index; Skin protection; Physical sunscreen; Chemical sunscreen; Sunburn.

1. Introduction

Sunscreen is a product used for the skin, containing ingredients that protect the skin from ultraviolet rays from the sun. Sunscreen is evaluated by two indices: SPF (Sun Protector Factor) and PA (Protection Grade of UVA). In particular, the SPF index determines the ability to block UVB rays (Ultra Violet B) and the PA index determines the ability to block UVA rays (Ultra Violet A). Sunscreen has a long history of formation and development. The world's first civilizations used plant extracts to protect their skin from ultraviolet rays. For example, around 3100-3000 BC, the ancient Greeks used olive oil, the ancient Egyptians preferred extracts from rice, jasmine and lupine – these substances still exist in current sunscreen products. In 1820, experiments conducted by Sir Everad Home showed that the reason for skin damage was mainly ultraviolet rays (UV rays) and not sunlight. More than 100 years later, in 1920, two German scientists, Hausser and Vahle, created the first commercial sunscreen containing benzyl salicylate and benzyl cinnamate that effectively absorbed UVB rays.

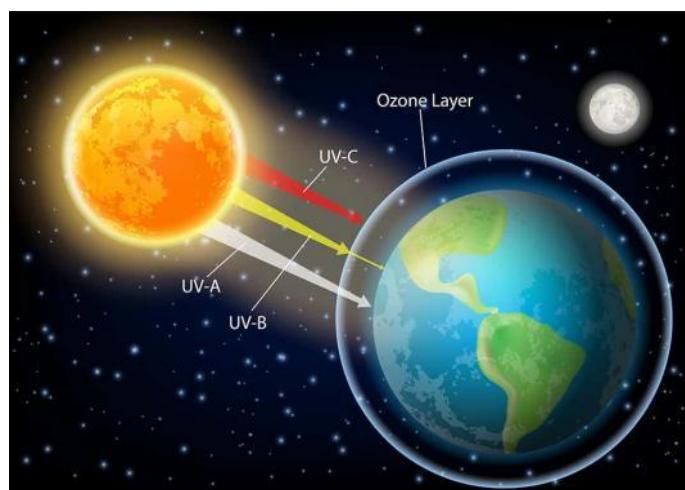


Figure 1. Description of wavelengths of types of ultraviolet rays reaching Earth [1]

Following that, a series of studies and different formulas for sunscreen were born from prominent names such as L'Oreal founder, and chemist Eugene Schueller. In the 1940s, sunscreen Sunlight is even classified as secret military research. In 1932, after a series of experiments, sunscreen was first widely marketed and continues to expand its market share to this day. Currently, the global Sunscreen Products market is predicted to grow from USD 15.38 billion in 2023 to USD 24.70 billion in 2030.

This study explores sunscreens, including contents such as factors from the sun that affect the skin, harmful effects of UV rays on the skin, important indicators in sunscreens, and main ingredients in sunscreens, and finally a conclusion about using sunscreen.

2. Factors from the sun affect the skin

UV rays is the abbreviation for Ultra Violet Radiation, which means ultraviolet rays or ultraviolet rays. UV rays in the early morning (before 7 a.m.) are beneficial for the skin, helping the skin supplement vitamin D. However, experts say that after 7 a.m., especially from 10 a.m. - 4 p.m., the intensity of UV rays increases. It will increase and if the skin is directly exposed to UV rays at the above time, it can cause negative effects on the skin and health. Sources that emit ultraviolet radiation include natural sources of UV radiation such as sunlight. Artificial sources of UV radiation such as sunbathing lamps, mercury vapor lamps, fluorescent lamps, halogen lamps.

Ultraviolet rays (UV rays) are divided into three main types: UVA rays (ultraviolet A); UVB rays (ultraviolet B); UVC rays (ultraviolet C).

2.1. UVA rays

UVA rays have a wavelength of about 320-400nm and account for 95% of UV rays reaching the earth, directly affecting humans. UVA rays have the ability to penetrate through the epidermis and penetrate deep into the dermis layer of the skin. They appear all year round, not only on sunny days but also on cloudy days. Long-term exposure to UVA rays can cause many problems for the skin, including: premature skin aging; symptoms of skin irritation; pigmentation disorders; increased risk of skin cancer. In short, UVA rays not only cause short-term problems for the skin but can also lead to long-term and dangerous problems for skin health.

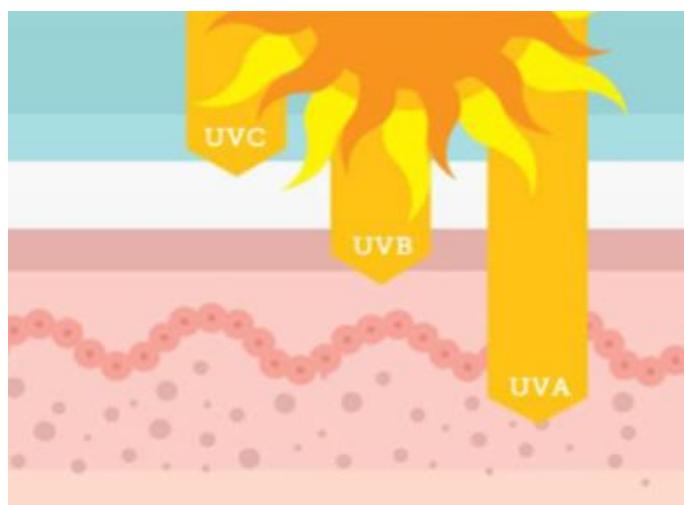


Figure 2. Description of the wavelengths of ultraviolet rays reaching the Earth and human skin [1]

2.2. UVB rays

UVB rays have a wavelength of about 290-320nm, accounting for 5% of the ultraviolet rays that can penetrate the ozone layer and directly contact the epidermis (outer layer of skin). Therefore, UVB rays are the direct cause of sunburn, skin darkening, skin darkening and, more dangerously, skin cancer. UVB rays in the early morning (before 7 am) are beneficial for the skin, helping the skin supplement vitamin D. In addition, UVB rays appear all year round but are most intense on hot days or in summer around 10 am – 4 pm. UVB rays cannot penetrate objects made of glass (glass doors, etc.).

2.3. UVC rays

UVC rays have a wavelength of about 100-280 nm. It is the ray with the highest energy among UV rays, but UVC rays are completely absorbed by the ozone layer and cannot pass through the atmosphere to reach human skin. Because of that, most sunscreens today do not protect against UVC rays. However, UVC rays can still be found from artificial sources such as germicidal lamps and mercury arc lamps and cause direct harm to human health, causing eye diseases.

3. Harmful effects of UV rays on human skin

Exposure to high-intensity, long-term UV rays can lead to serious consequences for human health:

3.1. Tanning

Tanning is the process in which skin pigment (melanin) located in the epidermis of the skin increases after exposure to UVB rays, leading to darkening of the skin. This is the body's natural defense process to protect the skin from UVB rays. Depending on the amount of melanin produced, when exposed to UVB rays, the skin can become tanned or sunburned - when melanin is not produced effectively, it can cause skin areas exposed to the sun to burn easily leading to sunburn.

3.2. Sunburn

Sunburn is the result of the skin's inflammatory response to exposure to UV rays, especially in the outermost cell layers of the skin. UVB rays are considered the main cause of sunburn in human skin. Signs of sunburn include: The skin becomes red, and painful and can range from mild burns to blisters. Often symptoms do not appear immediately after exposure to high-intensity UVB rays but can take up to five hours to manifest on the skin.

3.3. Sun allergy

Scientists believe that the cause of light allergies comes from UVA rays contained in sunlight. When UVA rays penetrate the skin, it will affect cells and change the properties of some proteins in skin cells. After being degraded, proteins will become foreign proteins and the body will eliminate them, causing allergies. Types of sun allergies include hives, which appear after a few minutes of exposure to UVA rays. Rashes, itching, and blisters will appear on the skin. This type of allergy will usually disappear if the patient is no longer directly exposed to high-intensity and long-term UVA rays. Chronic actinic dermatitis is the appearance of many rough, itchy patches on the skin surface. The location of damage is often located in areas of skin exposed to the sun such as the face, arms, legs, and neck. This type of allergy will not disappear on its own when the person stops being exposed to UVA rays but needs

to be treated promptly and appropriately. Rosacea is a form of sun allergy that appears when the skin is exposed to UV radiation. UV rays will combine with some ingredients in cosmetics such as emulsifiers, causing irritation and sebaceous follicle inflammation, causing abnormal capillary dilation. In conditions where the skin is irritated by UV rays, bacteria will more easily penetrate and grow, causing inflammatory acne.

3.4. Premature aging

UVA rays penetrate deeply into the dermis layer of the skin, destroying collagen structure at a higher rate than the normal skin aging process. To do this, UVA rays penetrate the middle layer of the skin (dermis), causing abnormal accumulation of elastin, which breaks down collagen. Prolonged exposure will cause this process to accelerate, leading to the formation of wrinkles and rapid sagging of the skin. In addition, the phenomenon of skin losing firmness, wrinkles, brown spots, and freckles appearing are also signs of aging skin.

3.5. Skin cancer

Skin cancer does not occur immediately, but is a process of long-term, high-intensity exposure to UVA and UVB rays that increases the risk of this disease. Exposure to UV rays damages and kills cells in the epidermis, creating a rough, scaly patch on the skin. If not detected and treated promptly, some of the stratum corneum on the skin can develop into cancer. According to actual statistics, nearly 90% of patients with skin cancer are due to UV damage. Some typical signs of skin cancer include the appearance of unusual red skin patches, moles, hard pimples or small tumors, and scaly and dry skin surface.

4. Important indicators in sunscreen

4.1. SPF index

SPF (sun protection factor) is an index that measures how long it takes for UVB rays to cause skin redness when using sunscreen compared to the time the skin is unprotected. This means that, after 10 minutes of sun exposure, a person's skin will become red, but when applying sunscreen with an SPF 15, that person's skin will be red after 150 minutes. The higher the SPF index, the stronger the protection against UVB rays.

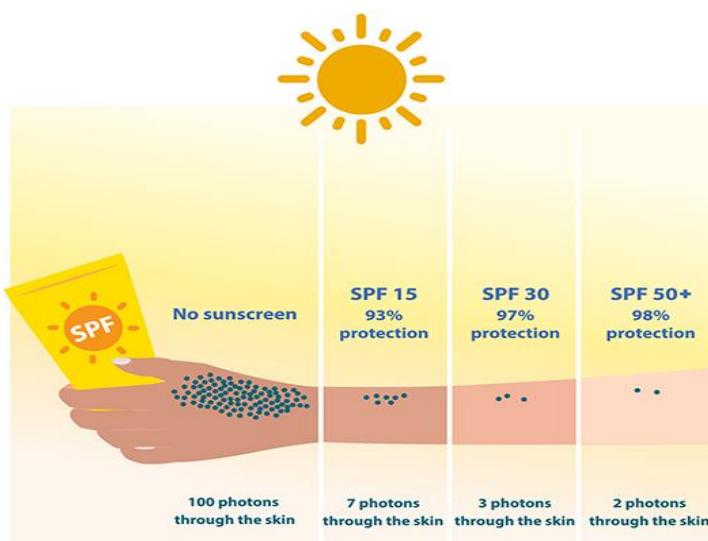


Figure 3. SPF index in sunscreen [2]

An index of 0 corresponds to zero UV radiation, which is essentially the case at night. An index of 10 roughly corresponds to midday summer sunlight in the tropics with clear skies. The lowest SPF index in sunscreen today is 15 and the highest is 100. When placed in perfect conditions, a sunscreen with SPF 15 will filter about 93.4% of UVB rays, SPF 30 is about 96.7%, and SPF 50 is about 98%. The ratio shows a negligible difference in ray-filtering between SPFs 15-50. And the reality is that SPF 30 sunscreen applied properly will provide better protection than SPF 50 sunscreen applied too thinly or not often enough. The purpose of this index is to help people protect themselves from ultraviolet rays, because too much exposure to sunlight will cause sunburn, eye damage such as cataracts, skin aging, and inhibit immunity, and skin cancer.

4.2. PA index

The PA index stands for Protection Grade of UVA and is an index measuring the ability of sunscreen to protect the body from UVA rays announced by the Japanese Cosmetic Association. There is no agreement on how to arrive at the PA value because the way it is measured is to measure the UVA rays that darken the skin unevenly. In fact, not all skin turns brown from sun exposure at the same rate. In other words, no one knows how long PA ratings last from person to person in real-world use.

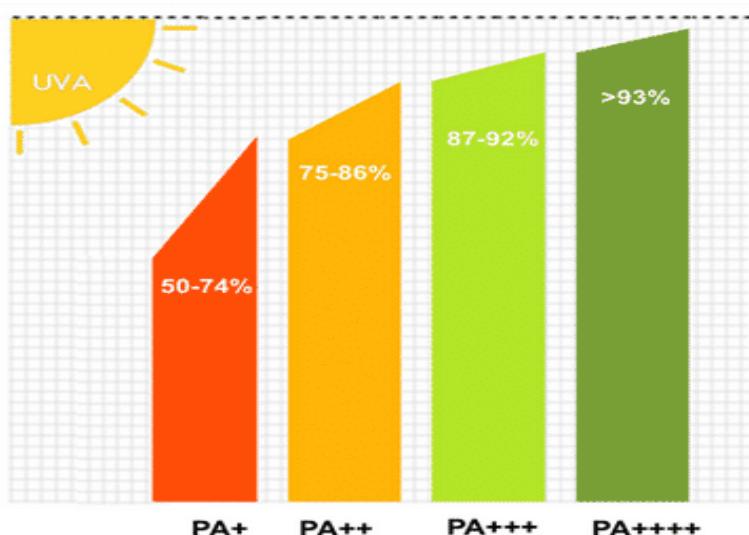


Figure 4. PA index and protection level [2]

Usually on sunscreen packaging, the PA index is poorly represented by "+" signs and it is divided into 4 levels: PA+ has the ability to resist UVA rays at a level of 40-50%; PA++ has better UVA protection, at 60-70% and has a filtering time of about 4-6 hours; PA+++: Good UVA protection, up to 90%, filtering time is about 8-12 hours; PA++++: Has very good UVA protection, up to over 95%. Filtering time is up to 16 hours. In general, the more pluses there are, the more protection there is from UVA rays. Note, that not all countries have upgraded to include PA++++. Some only recognize PA+++ as the highest UVA protection available. Therefore, when going outdoors, you should choose sunscreens with PA+++ or PA++ to provide better protection and longer protection time.

4.3. Other symbols on sunscreen

Not only UVA and UVB rays, but also visible light and infrared light also cause some harmful effects to the skin. Therefore, new generation very broad spectrum sunscreens have added substances that can block and filter these

types of light. Currently, we will encounter additional symbols such as HEVL (High Energy Visible Light 400-500nm): the ability to filter light visible to the naked eye; IR-A (infrared radiation A 750-1400nm): the ability to filter near-infrared rays.

5. Sunscreen ingredients in sunscreen

5.1. Chemical sunscreen ingredients

Chemical sunscreens work by absorption. However, sunscreen ingredients are not always able to completely block all three UV rays with equally high efficiency. Furthermore, their effects will not be the same for each skin type such as dry skin, oily skin, and acne skin. In addition, the durability of compounds also varies under the influence of the environment, so sunscreen products are a combination of a complex of multi-substance ingredients. Tinosorb S and Tinosorb M: are popular ingredients in Europe, Tinosorb S can protect from UVA, and long and short UVB rays. It thus becomes one of the most ideal ingredients to prevent sun damage. Tinosorb also stabilizes other sunscreen filters and is approved for use in concentrations up to 10%. However, the US Food and Drug Administration (FDA) has not approved this ingredient for some reasons, but it is accepted in some other countries such as Australia, Japan and Europe. The best benefit that Tinosorb brings is that it is an antioxidant and prevents the effects of sunlight. This ingredient is often added to sunscreens to increase effectiveness, and no high-risk factors have been identified.

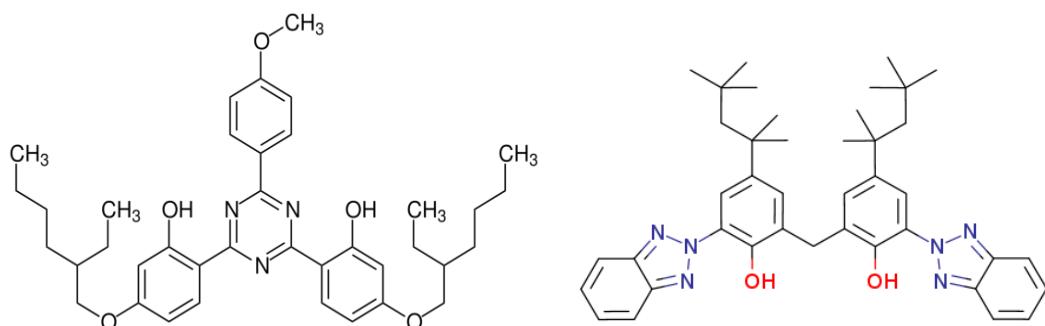


Figure 5. Tinosorb S (left) and Tinosorb M (right) [3-4]

Mexoryl SX: is a UV filter used in sunscreens and lotions globally. It has the ability to block UVA1 rays, which are long-wave rays that cause skin aging. A 2008 review found it to be an effective UV absorber and ideal for preventing sun damage. Although the ingredient has been marketed in Europe since 1993, the FDA did not approve the Mexoryl SX ingredient for L'Oréal until 2006. Currently, Mexoryl SX is approved for use in adults and children over 6 months old. When combined with avobenzene, the UVA protection of both ingredients increases effectiveness and stability.

Oxybenzone: commonly found in broad-spectrum sunscreens that filter both UVB and UVA rays (specifically short UVA rays). This is also one of the most common ingredients, found in most sunscreens on the US market, and can account for concentrations up to 6%. However, this ingredient was banned in Hawaii after a study conducted by the Haereticus Environmental Laboratory found that this ingredient contributes to bleaching and is toxic to coral reefs. For environmental reasons, many people have chosen not to use products containing Oxybenzone, instead looking for environmentally friendly green sunscreens. Recently, a study found that our skin

absorbs sunscreen ingredients like oxybenzone. This has caused heightened interest in safe sunscreens, although the study reported no harm and concluded. These results do not suggest that people should limit their use of sunscreens. In addition, another study also showed that oxybenzone does not cause significant endocrine disruption. Sunscreen containing oxybenzone has the ability to protect the skin from the effects of sunlight and prevent burning. However, if your skin is sensitive, you should be careful when using this product as it may cause skin irritation.

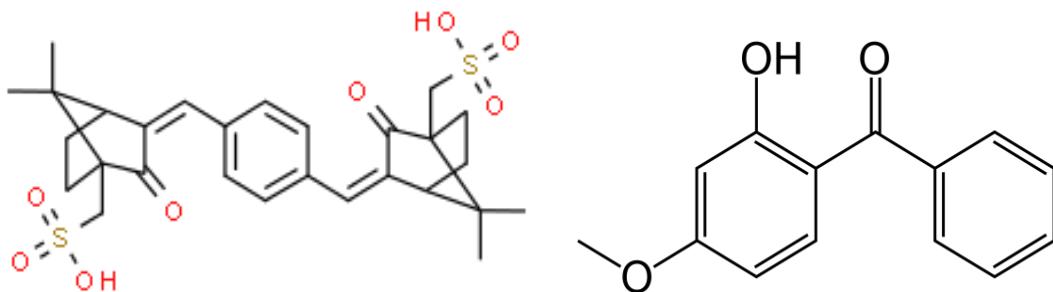


Figure 6. Mexoryl SX (left) and Oxybenzone (right) [3-4]

Octinoxate: is a popular and powerful UVB absorber, which means it is effective in preventing the effects of the sun. When combining octinoxate with avobenzone, they can provide excellent universal protection against sunburn and aging. This ingredient is allowed in formulations (up to a concentration of 7.5%), but octinoxate is banned in Hawaii due to environmental risks to coral reefs.

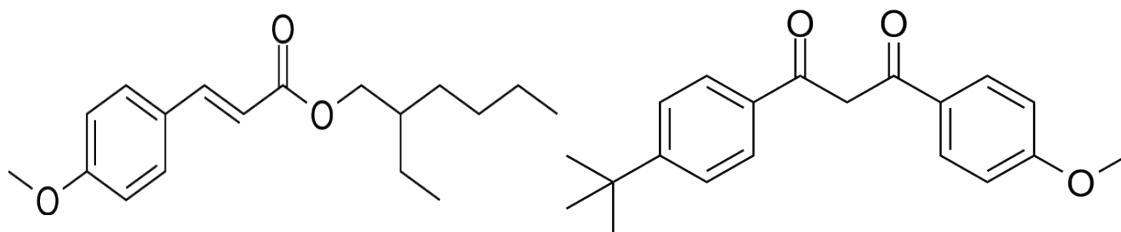


Figure 7. Octinoxate (left) and Avobenzone (right) [5-6]

Avobenzone: commonly used to block all UVA rays and is reported to be unstable in physical sunscreens. By nature, this ingredient will destabilize when exposed to light. To combat this, it is often combined with other ingredients (like mexoryl). In many countries, avobenzone is used in combination with zinc oxide and titanium dioxide, but in the United States, this combination is not allowed. Although it is found in broad-spectrum sunscreens and is often combined with other compounds, avobenzone loses 50 to 90% of its filtering ability within an hour of exposure to light. In the US, the Food and Drug Administration considers this ingredient safe but limits its concentration in sunscreen formulations to 3%.

5.2. Physical sunscreen ingredients

Physical sunscreen works by reflecting light. There are two sunscreen ingredients recognized by the FDA as safe and effective, both zinc oxide and titanium dioxide are physical sunscreen ingredients. These two ingredients are very strong against both UVA and UVB rays. In particular, they will not irritate the skin, so it is the perfect choice

for people with skin easily irritated by sunscreen. Titanium dioxide (TiO₂): acts as a broad-spectrum UV filter (although it does not block long-term UVA1 rays). The FDA (Food and Drug Administration) has approved the use of titanium dioxide in children over 6 months of age, and research shows it is generally safer than other sunscreens when in contact with the skin. According to a 2011 review, oral exposure of nano titanium dioxide is considered potentially carcinogenic to humans, based on the animal studies that have been performed.

Zinc oxide (ZnO): is the second approved sunscreen ingredient with concentrations up to 25%. Studies have shown that it is safe and shows no evidence of skin penetration even after repeated use. In Europe, this ingredient is labeled with a warning because of its toxicity to aquatic life. However, this ingredient is not harmful unless swallowed or inhaled. Compared to avobenzone and titanium dioxide, zinc oxide is considered harmful, it is light sensitive, effective and safe for sensitive skin. On the other hand, research also shows that it is not as effective as chemical sunscreens and is not effective in protecting the skin from sunburn and other sun damage.

6. Conclusion

Through the above essay, we have seen the significant harmful effects of UV rays on human skin. Therefore, sunscreen is a truly necessary product, especially at the present time when the UV index in Vietnam is very high. Nowadays, people are concerned about their skin, so the need to buy sunscreen is very high. Therefore, some ingredients are producing fake and counterfeit goods on the market, so we should choose to buy products at reputable stores such as Hasaki, Gaurdian, etc. to avoid harm to the skin. Choose sunscreen suitable for your skin type. Currently, many people use sunscreen according to trends without finding out whether it is suitable for their skin. When buying, we need to see information about which skin type to use. If used inappropriately for your skin, it may cause skin irritation. Sunscreen can only protect the skin for a certain period of time, so we need to reapply it many times a day to protect the skin optimally. In particular, we need to use makeup remover combined with facial cleanser to remove sunscreen as much as possible, avoiding residual cream on the skin that causes acne. In the future, there needs to be solutions to create advanced and user-friendly sunscreens on the market to reduce consumer concerns about the safety of sunscreens and light coverage in the spectrum, wide and visible as well as their harmful impact on the environment.

Declarations

Source of Funding

The study has no funding from any institution.

Competing Interests Statement

The author declares having no competing interest with any party concerned during this publication.

Consent for Publication

The author declares that he consented to the publication of this study.

Authors' contributions

All research work is from the author.

Availability of data and material

All data pertaining to the research is kept in good custody by the author.

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